Original Article

Efficacy of the three-point cuff palpation technique in preventing endobronchial tube migration during positioning in robotic pelvic surgeries

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ABSTRACT

Background and Aims: During robotic pelvic surgeries, the shortening of endotracheal tube (ETT) tip-to-carina distance (D_{TC}) during pneumoperitoneum with 45^0 Trendelenburg position can result in endobronchial tube migration. In the three-point ETT cuff palpation (TPP) technique, maximal ETT cuff distension is felt over the tracheal segment located between the cricoid-thyroid membrane and suprasternal notch, which is likely to provide optimal placement. However, the reproducibility and reliability of the TPP technique in preventing endobronchial tube migration are yet to be evaluated. Hence, we compared three ETT placement techniques: TPP technique, intubation guide mark (IGM) technique and Varshney's formula (VF) for the prevention of endobronchial tube migration during robotic pelvic surgeries. **Methods:** ETT placement by TPP was compared with IGM and VF techniques in 100 American Society of Anesthesiologists physical class II-III patients, by assessing the serial changes in D_{TC} and incidence of endobronchial tube migration throughout the different phases of pneumoperitoneum and Trendelenburg position using t-test and Chi-square test. Changes in the D_{TC} during various phases were also measured. **Results:** D_{TC} (mean ± standard deviation) at baseline and during pneumoperitoneum was significantly better in TPP technique (2.80 ± 0.62 cm and 1.96 ± 0.66 cm) as compared to both IGM (2.50 ± 1.27 cm and 1.41 ± 1.29 cm) and VF techniques (1.83 ± 1.13 cm and 0.98 ± 1.18 cm), $P < 0.001$. During pneumoperitoneum, the mean shortening of D_{TC} was 0.84 ± 0.20 cm, and no endobronchial tube migration was found in TPP technique compared to 20% in IGM and 25% in VF techniques, $P < 0.001$. **Conclusion:** TPP is a simple and reliable technique, which provides optimal ETT placement and prevents endobronchial tube migration throughout the different phases of robotic pelvic surgeries.

Key words: Endotracheal intubation, pneumoperitoneum, robotic surgical procedures, Trendelenburg position

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INTRODUCTION

In laparoscopic pelvic surgeries, tracheal shortening of up to 1.5 cm has been reported in 13.6–27%[1-3] patients, leading to the reduced endotracheal tube (ETT) tip–carina distance (D_{TC}) and the possibility of endobronchial tube migration during pneumoperitoneum with Trendelenburg position. Tracheal shortening has additionally been reported with raised intra-abdominal pressure[2] and neck flexion.[4] Optimal placement (D_{TC} ≥2.5 cm)[5] could prevent endobronchial tube migration during pneumoperitoneum in the Trendelenburg position.

For achieving optimal D_{TC}, ETT placement techniques like suprasternal-notch cuff palpation,[6] intubation guide mark (IGM),[7] 21/23 cm fixed-depth technique,[8]

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Varshney's formula (VF),[9] Chula's formula, etc., are commonly practised with variable success rates.

In Indian adults, the reported average cricoid-to-carina distance (D_{CrC}) is 9.7–11.2 cm in males and 9.4–10.4 cm in females.[9,10] Hence, while securing the ETT by the IGM technique, placing fixed length (≈ 9 cm) of commercially available tubes beyond the vocal cords could lead to suboptimal placement.[9] However, placing the proximal cuff just beyond the cricoid-cartilage is likely to provide optimal ETT placement as only around 6–7 cm segment of the ETT (between proximal end of cuff to tube tip) lies beyond the cricoid.

After ETT placement, the cuff can be palpated externally over three locations (cricothyroid membrane, suprasternal notch and tracheal segment between these two landmarks) while pressing the pilot balloon. The proximal end of the cuff is likely to be placed just beyond the cricoid-cartilage when the maximal distension of ETT cuff is felt between the cricothyroid membrane and suprasternal notch. We named this technique of ETT placement as the 'three-point cuff palpation (TPP)' technique.

This study aimed to evaluate the efficacy of TPP technique as compared to IGM and VF techniques in maintaining optimal D_{TC} and preventing endobronchial tube migration during robotic pelvic surgery by comparison of D_{TC} and the estimated incidence of endobronchial migration.

METHODS

This prospective interventional study was conducted at a tertiary cancer care institute, after approval from the institutional review board (RGCI/IRB/231/2018), and registration with the clinical trials registry (NCT04440787). The codes laid by Helsinki declaration were followed.

American Society of Anesthesiologists physical status II-III patients (20-75 years) requiring robotic pelvic surgeries for abdominal malignancy provided written informed consent and were enroled from December 2018 to September 2021. Patients with body mass index (BMI) >40 kg/m^2, history of previous tracheal surgeries and with tracheal deviation due to large neck swelling were excluded.

After the induction of anaesthesia, oral intubation was performed with 7.0 mm and 8.0 mm internal diameter (ID) Hi-Low polyvinyl chloride Portex® cuffed ETT (Smith Medical ASD, Minneapolis, USA) in all female and male participants, respectively. After auscultation and capnographic confirmation, patients were ventilated with a tidal volume of 8 ml/kg, positive end expiratory pressure of 5 cm of water, and end-tidal carbon dioxide was kept between 36 and 44 mmHg. During pneumoperitoneum and the 45^0 Trendelenburg position, intra-abdominal pressure was kept constant at 15 mm Hg.

The obtained length of insertion of ETT measured at the angle of mouth was denoted by 'L' followed by the name of ETT placement technique in subscript. For example, the length of insertion of ETT by IGM technique was represented by L_{IGM}. Various time-points of measurement of D_{TC} in robotic surgery were as follows: T0 at intubation in the supine position, T1 at pneumoperitoneum in the supine position, T2 after 10 minutes of Trendelenburg position, T3 after 1 hour of Trendelenburg position and T4 before extubation in supine position. During dynamic tracheal shortening, change in distance between particular landmarks from its baseline value was represented by putting prefix 'Δ' in front of D. For example, change in D_{TC} value was denoted by ΔD_{TC}. At T0 time-point, ETT was placed by IGM technique.[7] However, ETT cuff distension was felt over all three tracheal locations as described in the introduction, and finally tubes were secured according to the TPP technique. If maximal distension was felt over the desired location and no ETT repositioning was required, then length of ETT insertion for TPP technique (L_{TPP}) was identical to L_{IGM}. However, if the relocation was required to achieve maximal balloon distension at the desired location, then L_{TPP} and L_{IGM} were different. The length of insertion for the VF technique (L_{VF}) was obtained by the below-mentioned formula as proposed by Varshney *et al*.[9]

L_{VF} = Height in (cm)/7-2.5 cm

This value was not applied in the patient but was used to estimate the D_{TC} by mathematical calculation. Once the lengths of insertion for all the three techniques were available, the difference between them (ΔL) was obtained by the below-mentioned formulae:

The difference between L_{TPP} and L_{IGM} provides Δ L1

$\Delta L1 = L_{TPP} - L_{IGM}$

Similarly, the difference between L_{TPP} and L_{VF} provides Δ L2

$\Delta L2 = L_{TPP} - L_{VF}$

After final ETT placement by TPP technique (T0 time-point), fibre-optic bronchoscopy (FOB) was performed by an anaesthetist. The measured tracheal distances included D_{TC}, D_{CrC}, vocal cord-to-cricoid distance (D_{VCr}) and vocal cord-to-carina distance (D_{VC}). To locate the proximal end of ETT cuff position, airway ultrasonography (USG) in the longitudinal plane was performed by the same anaesthetist. In the subsequent time-points, only D_{TC} measurements were performed using FOB. Measurements using FOB and airway USG were performed as described in the previous literature.[10,11]

Once the D_{TC} for TPP technique was measured at the various time-points, ΔL1 and Δ L2 were adjusted from this value to obtain D_{TC} value for both IGM and VF techniques for all the time-points [Table 1].

D_{TC} (IGM) = D_{TC} (TPP) ± ΔL1

D_{TC} (VF) = D_{TC} (TPP) ± ΔL2

As the tracheal length changes throughout different phases of surgery, change in D_{TC} values (ΔD_{TC}) at T1–T4 time-points were obtained by deducting the D_{TC} value of a particular time-point from its baseline (T0) value. For example, if we want to find the change in D_{TC} at pneumoperitoneum ($\Delta D_{TC}1$), then the measured $D_{TC}1$ value at pneumoperitoneum was subtracted from the baseline $D_{TC}0$ value.

$\Delta D_{TC}1 = D_{TC}0 - D_{TC}1$

Table 1: Method of measuring and obtaining different tracheal distances in TPP, IGM and VF techniques at various time-points throughout the robotic surgery

Distance at different time-points	TPP technique	IGM technique (derived)	VF technique (derived)
$D_{TC}0$	FOB	$D_{TC}0 \pm \Delta L1$	$D_{TC}0 \pm \Delta L2$
$D_{TC}1$	FOB	$D_{TC}1 \pm \Delta L1$	$D_{TC}1 \pm \Delta L2$
$D_{TC}2$	FOB	$D_{TC}2 \pm \Delta L1$	$D_{TC}2 \pm \Delta L2$
$D_{TC}3$	FOB	$D_{TC}3 \pm \Delta L1$	$D_{TC}3 \pm \Delta L2$
$D_{TC}4$	FOB	$D_{TC}4 \pm \Delta L1$	$D_{TC}4 \pm \Delta L2$
$\Delta D_{TC}1$	$D_{TC}0 - D_{TC}1$	$\Delta D_{TC}1 \pm \Delta L1$	$D_{TC}1 \pm \Delta L2$
$\Delta D_{TC}2$	$D_{TC}0 - D_{TC}2$	$\Delta D_{TC}2 \pm \Delta L1$	$D_{TC}2 \pm \Delta L2$
$\Delta D_{TC}3$	$D_{TC}0 - D_{TC}3$	$\Delta D_{TC}3 \pm \Delta L1$	$D_{TC}3 \pm \Delta L2$
$\Delta D_{TC}4$	$D_{TC}0 - D_{TC}4$	$\Delta D_{TC}4 \pm \Delta L1$	$D_{TC}4 \pm \Delta L2$

D_{TC}: endotracheal tube tip-to-carina distance, ΔDTC: change in endotracheal tube tip-to-carina distance during different phases of robotic surgery, ΔL1: difference in length of insertion between TPP and IGM techniques and ΔL2: difference in length of insertion between TPP and VF techniques. T0: after intubation in the supine position, T1: after pneumoperitoneum in the supine position, T2: after ten minutes of pneumoperitoneum in Trendelenburg position, T3: after one hour of pneumoperitoneum in Trendelenburg position and T4: before extubation in the supine position

Similarly, the $\Delta D_{TC}2$ to $\Delta D_{TC}4$ were obtained for the TPP technique [Table 1].

Based on the $\Delta D_{TC}1$ to $\Delta D_{TC}4$ values of TPP technique, the $\Delta D_{TC}1$ to $\Delta D_{TC}4$ values for both IGM and VF techniques were derived by adjusting the ΔL1 and ΔL2 from it, as shown below [Table 1].

$\Delta D_{TC1\text{-}4}$ (IGM) = $\Delta D_{TC1\text{-}4}$ (TPP) ± ΔL1

$\Delta D_{TC1\text{-}4}$ (VF) = $\Delta D_{TC1\text{-}4}$ (TPP) ± ΔL2

ETT placement was then categorised as optimal, suboptimal and endobronchial placements based on the measured D_{TC}. Due to the reported 1.5 cm displacement of ETT tip towards the carina due to shortening of trachea during pneumoperitoneum,[1,2] the cut-off D_{TC} value for categorising ETT placement was different with pneumoperitoneum (T1-3) and without pneumoperitoneum (T0 and T4). In the absence of pneumoperitoneum, tube placements were categorised as optimal ($D_{TC} \geq 2.5$ cm), suboptimal (D_{TC} 0 to <2.5 cm) and endobronchial. However, during pneumoperitoneum it was categorised as optimal ($D_{TC} \geq 1$ cm), suboptimal (D_{TC} <1-0 cm) and endobronchial.

Based on the 27% reported incidence of ETT migration during laparoscopic pelvic surgeries,[1] we assumed that the TPP technique could bring down this incidence to <10%. Power analysis with β (0.2) and α (0.1) indicated that 29 patients in each group were required, and hence, we took 100 patients. In this study, while comparing all three ETT placement (IGM, TPP and VF) techniques, every participant was the control for himself/herself, as it was the only way to rule out the inter-participant variation regarding the anthropometric parameters, tracheal dimensions and ETT size.

Continuous data were described as mean [standard deviation (SD)] while count data were summarised as numbers (proportion). Reliability of cuff localisation by palpation was evaluated by finding inter-rater agreement between cuff palpation and its USG localisation by Cohen's weighted kappa with linear weights test. Optimal placement and prevention of ETT migration between the techniques were assessed by Chi-square test. Among the techniques, D_{TC} and ΔD_{TC} values were compared by paired t-test. The ability to discriminate optimal and suboptimal ETT placement among the techniques was assessed by receiver operating characteristic (ROC) curves, and the area under the curve (AUC) was plotted. Trends of Δ D_{TC} among the three techniques in maintaining optimal D_{TC} throughout the different phases of tracheal shortening were shown by a time-series graph.

All statistical tests were two-tailed, and alpha <0.05 was set as significant beforehand. Descriptive statistics, kappa statistics and ROC were analysed using MedCalc Statistical Software version 15.8 (MedCalc Software bvba, Ostend, Belgium). Longitudinal secular trends of D_{TC} for all three techniques were analysed and drawn using the R program [R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria] utilising following packages: 'ggplot2', 'ggpubr' and 'dplyr'.[12]

RESULTS

Out of 110 enroled patients, 100 participants were statistically analysed, and ten were excluded due to non-localisation of the ETT cuff on USG.

The demographic, upper airway topographical distances and surgical details of all 100 patients were tabulated [Table 2]. A total of 500 measurements were taken for obtaining D_{TC} at various time-points.

At intubation, 41% tube placements by IGM technique required repositioning to achieve TPP placement, $P < 0.0001$. While evaluating reliability of cuff palpation for tube placement in TPP technique, excellent agreement was found between the cuff palpation and its sonographic localisation. For asserting absence of ETT cuff at cricoid-thyroid membrane (κ = 0.86, standard error (SE) = 0.10, 95% confidence interval (CI) = 0.66 to 1.00), a very good agreement was found. However, for locating ETT cuff between cricothyroid membrane and suprasternal notch (κ = 0.95, SE = 0.05, 95% CI = 0.86 to 1.00), and at suprasternal notch (κ = 0.92, SE = 0.06, 95% CI = 0.81 to1.00), a near-perfect agreement was found [Table 3].

At T0, T1 and T2 time-points, significantly better D_{TC} values 2.80 ± 0.62 cm, 1.96 ± 0.66 cm and 2.58 ± 0.63 cm were obtained in the TPP technique compared to 2.50 ± 1.27 cm, 1.41 ± 1.29 cm and 2.06 ± 1.20 cm in IGM and 1.83 ± 1.13 cm, 0.98 ± 1.18 cm and 1.60 ± 1.21 cm in VF techniques, $P < 0.0001$ [Tables 3 and 4].

Maximal tracheal shortening was observed at T1 time-point ($\Delta D_{TC}1$ = 0.84 ± 0.20 cm), while it was minimal at both T2 ($\Delta D_{TC}2$ = 0.22 ± 0.46 cm) and T3 ($\Delta D_{TC}3$ = 0.19 ± 0.46 cm) time-points [Table 4]. However, minimal tracheal elongation was observed at T4 time-point ($\Delta D_{TC}4$ = -0.03 ± 0.26 cm). When change in ΔD_{TC} at different surgical phases among the techniques was plotted on a time-series data graph, it showed endobronchial tube migration in both IGM and VF techniques at different time-points compared to no endobronchial tube migration at any time-point in TPP technique [Figure 1a-c].

Table 2: Details of demographic parameters, measurements of upper airway topographical distances, details of various robotic surgical procedures and duration of surgery

Variables	Mean±SD
*Age (years)	56.33±11.85
*Height (cm)	161.45±8.99
#Geometric mean weight (kg)	69.32
#Geometric mean BMI (kg/m^2)	26.73
^Gender, males/females, *n* (%)	54 (54)/46 (46)
*Mentohyoid distance (cm)	3.49±0.67
*Thyromental distance (cm)	5.07±0.84
*Cricoid-suprasternal notch distance (cm)	3.30±1.13
*Thyroid-suprasternal notch distance (cm)	5.80±0.98
	***n* (%)**
^Types of robotic surgeries	
RALP	36 (36)
RCP	15 (15)
RPLND	10 (10)
RH	39 (39)
*Duration of surgery (minutes)	190±6

D'Agostino-Pearson was used for obtaining mean±SD, ^Proportions by frequency tables, #Logarithmic transformation of data was used to derive geometric means, *Represent the data evaluated as mean±SD. RALP: robotic-assisted laparoscopic prostatectomy, RCP: robotic cysto-prostatectomy, RPLND: robotic retroperitoneal lymph node dissection, RH: robotic hysterectomy, SD: standard deviation, BMI: body mass index, *n*: number

At T0 time-point, ETT placements were optimal in 86% of TPP placements as compared to 57% in IGM and 37% in VF placements, $P < 0.0001$ [Table 5]. Similarly, at T1 and T2 time-points, 98% and 100% of the tube placements using TPP technique were optimal as compared to 64% and 78% in IGM and 52% and 71% in VF technique, $P < 0.0001$ [Table 5].

At T0 time-point, no endobronchial tube migration was found in TPP technique as compared to 1% in IGM and 6% in VF technique, $P < 0.0001$ [Table 5]. Similarly, at T1 and T2 time-points, no endobronchial migration was found in TPP technique compared to 20% and 2% in IGM and 25% and 7% in VF, $P < 0.0001$ [Table 5].

ROC analysis for optimal tube placement between the techniques demonstrated excellent placements in TPP [AUC 0.99 (95%CI 0.95-1.00, $P < 0.0001$), as

Table 3: Airway length parameters of the patients, depth of tube insertion and endotracheal tube (ETT) tip-to-carina distances and agreement between cuff palpation and sonographic localisation of ETT cuff

Variables	Mean±SD
*Total tracheal length from vocal cords to carina (cm)	11.27±1.47
*Vocal cord-to-cricoid distance (cm)	2.67±0.53
*Carina-to-cricoid cartilage distance (cm)	8.46±1.74
*Length of endotracheal tube insertion in TPP (cm)	19.25±1.45
*Length of endotracheal tube insertion in IGM (cm)	20±1.25
*Length of endotracheal tube insertion in VF (cm)	20.45±1.30
*Endotracheal tube tip-to-carina distance (DTC)	
TPP technique (cm)	2.80±0.62
IGM technique (cm)	2.50±1.27
VF technique (cm)	1.83±1.13
	Mean±SD (cm), SE, 95%CI, *P*
^*Difference between the carina to tube tip distance (DTC) among the techniques at intubation	
IGM and TPP (cm)	-0.54±0.86, 0.08, -0.71 to -0.36, <0.0001
VF and TPP (cm)	-0.98±0.96,0.09, -1.17 to -0.79, <0.0001
VF and IGM (cm)	-0.44±1.01, 0.10, -0.64 to -0.24, <0.0001
	Kappa, SE, 95%CI
#Agreement between endotracheal tube cuff palpation and ultrasound-guided localisation at various tracheal locations	
Absence of endotracheal tube cuff above cricoid-cartilage	0.86, 0.10, 0.657-1.000
Presence of endotracheal tube cuff below cricoid-cartilage	0.95, 0.05, 0.856-1.000
Presence of endotracheal tube cuff at the supra-sternal notch	0.92,0.06, 0.812-1.000

D'Agostino-Pearson was used for obtaining mean±SD, *Represent the data evaluated as mean±SD, ^Difference between D_{TC} values by paired *t*-test, #Cohen's weighted kappa with linear weights test was used to obtain agreement between cuff palpation and ultrasound guided localisation. TPP: three-point cuff palpation, IGM: intubation guide mark, VF: Varshney's formula for assessing depth of endotracheal tube insertion. SD: standard deviation, SE: standard error, CI: confidence interval, ETT: endotracheal tube

Table 4: ETT tip-to-carina distance (D_{TC}) in all three tube placement techniques and the mean change (ΔD_{TC}) at various phases of robotic surgery

*Endotracheal-tube tip-to-carina distance	TPP technique (mean±SD)	IGM technique (mean±SD)	VF technique (mean±SD)
$D_{TC}0$ (cm)	2.80±0.64	2.27±1.27	1.83±1.12
$D_{TC}1$ (cm)	1.96±0.66	1.41±1.29	0.98±1.18
$D_{TC}2$ (cm)	2.58±0.63	2.06±1.20	1.60±1.21
$D_{TC}3$ (cm)	2.61±0.61	2.08±1.23	1.64±1.21
$D_{TC}4$ (cm)	2.85±0.66	2.30±1.28	1.87±1.20
*$\Delta D_{TC}1$ (cm), *P*	-0.84±0.20, <0.0001	-0.84±0.21, <0.0001	-0.85±0.25, <0.0001
$\Delta D_{TC}2$ (cm), *P*	-0.22±0.46, <0.0001	-0.20±0.48, 0.0001	-0.22±0.54, 0.0001
$\Delta D_{TC}3$ (cm), *P*	-0.19±0.45, 0.0001	-0.18±0.48. 0.0003	-0.18±0.54, 0.0013
$\Delta D_{TC}4$ (cm), *P*	0.04±0.26, 0.0796	0.04±0.26, 0.1022	0.04±0.35, 0.2545

Mean D_{TC} by D'Agostino-Pearson test,* Represent the data evaluated as mean±SD, ^Difference between D_{TC} values by paired *t*-test. TPP: three-point cuff palpation, IGM: intubation guide mark, VF: Varshney's formula for assessing depth of endotracheal-tube insertion, SD: standard deviation, ETT: endotracheal tube. *ΔD_{TC} 1-4: change in D_{TC} at time-points T1-T4

compared to IGM [0.79 (95% CI 0.70-0.87, $P < 0.0001$)] and VF [0.76 (95%CI 0.67-0.85)]. Differences in AUC between TPP and IGM (0.196, 95%CI 0.09-0.30, *P* 0.0003) and TPP and VF (0.22, 95% CI 0.05-0.39, $P = 0.0084$) were found to be statistically significant [Figure 1d].

Lastly, we did not locate ETT cuff below the cricothyroid membrane in any patient at any time-point.

DISCUSSION

TPP technique was successful in preventing endobronchial tube migration during dynamic shortening of the trachea in robotic pelvic surgeries and overcoming the 1.5 cm displacement of ETT tip towards the carina during pneumoperitoneum.

The maximal L_{VF} (20.45 ± 1.30 cm) was found in VF technique, as compared to 20 ± 1.25 cm in IGM technique and 19.25 ± 1.45 cm in TPP technique. Consequently, significantly better mean D_{TC} was observed in TPP technique (2.80 ± 0.62 cm) as compared to IGM (2.50 ± 1.27 cm) and VF (1.83 ± 1.13 cm) technique. Least L_{TPP} could be explained by positioning the proximal end of ETT-cuff just below the cricoid-cartilage; however, in both IGM and VF techniques, it was placed deeper. In spite of close approximation of ETT cuff with cricoid-cartilage

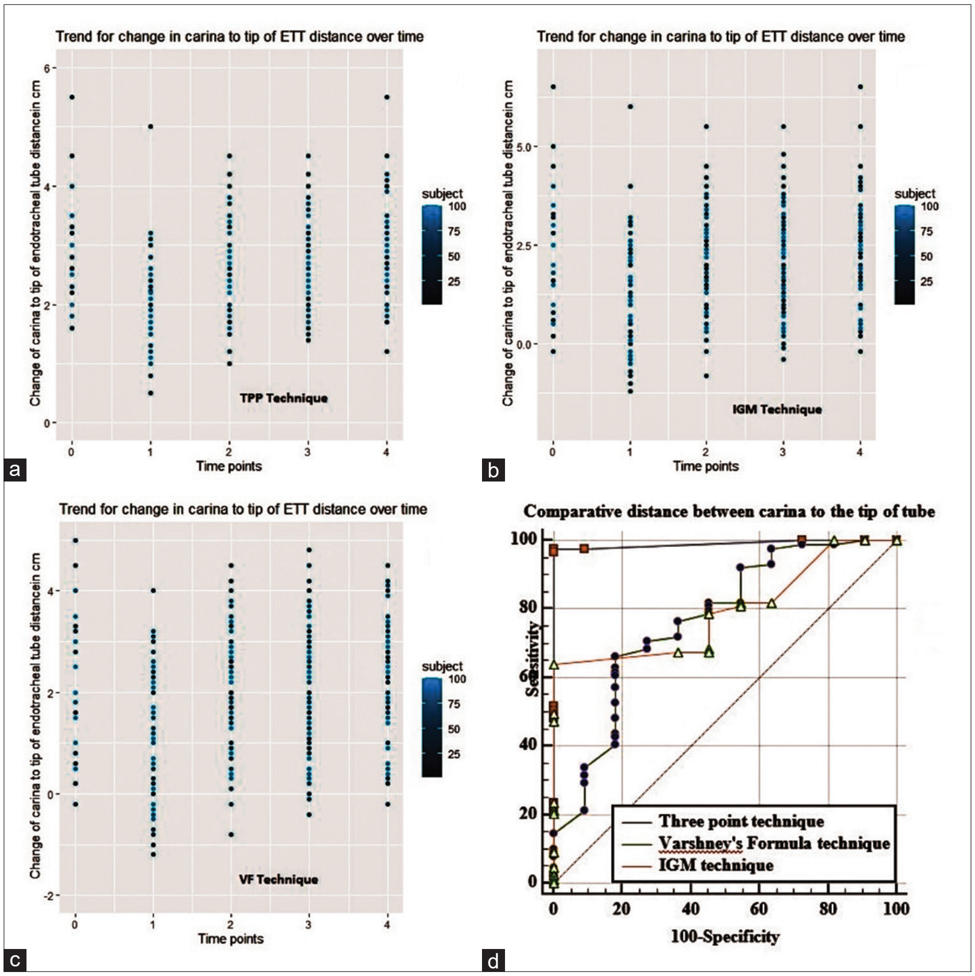

Figure 1: Trend of change in endotracheal tube tip to carina distance (TCD) at all time points (T0-T5) for each patient. (a) Three point cuff palpation (TPP) technique. (b) Intubation guide mark (IGM) technique and (c) Varshney's formula (VF) technique. (d) Area under receiver operating curve showing discriminative ability for optimal tube placement between TPP, IGM and VF technique

Table 5: Incidence of optimal ETT placement and ETT migration among all three tube placement techniques at various time-points

Time-points	TPP	IGM	*P*	TPP	VF	*P*	IGM	VF	*P*
Optimal endotracheal-tube placements *n* (%)									
T0	86 (86%)	57 (57%)	<0.0001	86 (86%)	37 (37%)	<0.0001	57 (57%)	37 (37%)	<0.0001
T1	98 (98%)	64 (64%)	<0.0001	98 (98%)	52 (52%)	<0.0001	64 (64%)	52 (52%)	<0.0001
T2	100 (100%)	78 (78%)	<0.0001	100 (100%)	71 (71%)	<0.0001	78 (78%)	71 (71%)	0.0002
T3	100 (100%)	78 (78%)	<0.0001	100 (100%)	71 (71%)	<0.0001	78 (78%)	71 (71%)	0.0011
T4	75 (75%)	52 (52%)	<0.0001	75 (75%)	36 (36%)	<0.0001	52 (52%)	36 (36%)	<0.0001
Endobronchial intubations *n* (%)									
T0	0 (0%)	1 (1%)	<0.0001	0 (0%)	6 (6%)	<0.0001	1 (1%)	6 (6%)	0.0626
T1	0 (0%)	20 (20%)	<0.0001	0 (0%)	25 (25%)	<0.0001	20 (20%)	25 (25%)	<0.0001
T2	0 (0%)	2 (2%)	<0.0001	0 (0%)	7 (7%)	<0.0001	2 (2%)	7 (7%)	0.3135
T3	0 (0%)	3 (3%)	<0.0001	0 (0%)	8 (8%)	<0.0001	3 (3%)	8 (8%)	0.5742
T4	0 (0%)	2 (2%)	<0.0001	0 (0%)	6 (6%)	<0.0001	2 (2%)	6 (6%)	0.2531

Chi-square test evaluated the incidence of optimal ETT placement and ETT migration. TPP: three-point cuff palpation, IGM: intubation guide mark, VF: Varshney's formula for assessing depth of endotracheal-tube insertion, ETT - endotracheal tube, *n* - number. Various time-points: T0: at intubation in the supine position, T1: pneumoperitoneum in the supine position, T2: 10 min after pneumoperitoneum in 45° Trendelenburg position, T3: after 1 h of pneumoperitoneum in 45° Trendelenburg position and T4: just before extubation in the supine position

in TPP technique, we did not find the ETT cuff positioned below the cricothyroid membrane at any time-point in any patient.

The observed total tracheal length (D_{VC}) was 11.27 ± 1.47 cm, and observed D_{CrC} was 8.46 ± 1.74 cm. Hence, during ETT placement by

IGM technique, putting the fixed length (≈ 9 cm) of ETT between the guide mark and ETT tip led to suboptimal tube placement in 43% patients. In a study on Indian population, even with higher mean D_{CrC} (9.83 ± 1.26 cm), suboptimal placements were reported during ETT placement by IGM technique.[9]

We did not find any endobronchial tube migration at the T1 time-point (phase of maximal tracheal shortening) in TPP as compared to 20% in IGM and 25% in the VF technique, $P < 0.0001$ [Table 4]. Our results are in concordance with one of the studies;[3] however, they differ from a couple of others.[1,2] The variance in endobronchial tube migration incidence during pneumoperitoneum could be due to the observed difference in tracheal shortening (0.84 cm in ours versus 1.4 cm in others).[1,2]

At pneumoperitoneum, the observed $\Delta D_{TC}1$ of 0.84 ± 0.2 cm was comparable to 0.7 cm reported by others.[3] However, in the combined pneumoperitoneum and Trendelenburg position, the observed $\Delta D_{TC}2$ was 0.22 ± 0.46 cm, which was less than that reported by others (0.6–1.4 cm).[1,2] This disparity could be related to the degree of Trendelenburg position. It was 45^0 in the present study as compared to 20^0–30^0 in other studies,[1-3] as steeper Trendelenburg position may proportionally elongate the trachea due to gravitational pull.[6]

Though cuff palpation for tube placement is a time-honoured and reliable technique,[6] it is a subjective and operator-dependent technique.[6] So, there always exists an element of human error. In a study, ETT cuff position in relation to the tracheal rings and other tracheal structures was correctly localised in all 100% of patients.[13] Hence, to objectively authenticate cuff palpation findings during TPP placement, airway USG was performed, and we found an excellent agreement at all locations ($\kappa = 0.86$-0.95). Such an excellent agreement validates cuff palpation as an inexpensive, simple and reliable method for tube placement by TPP technique, as claimed earlier.[6] All-inclusive, these observations make a strong case for the utility of the TPP technique in providing optimal tube placement and in ensuring adequate D_{TC} throughout the various phases of tracheal shortening.

The main limitation of the TPP technique is that the correct placement of ETT is subjected to cuff palpation. Hence, patients with indistinct tracheal surface landmarks (excessive fat, post-radiation and short neck) and clinicians not habitual of cuff palpation might not be able to correctly place the ETT by TPP technique. However, cuff palpation for tube placement has a short learning curve, and clinicians can easily acquire this skill. Prevention of endobronchial tube migration using TPP technique in less than 45^0 Trendelenburg position and in patients with BMI >40 kg/m^2 is yet to be evaluated.

CONCLUSION

TPP technique is a simple, reproducible and reliable technique, capable of ensuring adequate D_{TC} and preventing endobronchial tube migration during various phases of tracheal shortening in robotic pelvic surgeries.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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